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or he would not say that in that case I "would not so easily produce a symmetrical  $F_2$  curve."

That he has not assimilated the significance of the inter-play of plus-acting and minus-acting factors is shown by his question:

If all factors involved in producing a character are "completely dominant," how can the character itself keep from being completely dominant?

The curves in my Fig. 1 are an adequate answer to this question.

Finally, it seems hardly necessary to point out the inadequacy of the case of the Blue Andalusian fowl, as a proof that inequalities in genotypic variation are not masked by fluctuations when the amount of fluctuating variation is large in comparison with the distances between the centers of genetic stability which are determined by the numerous factor combinations putatively involved in the several examples cited in Castle's original paper.

GEO. H. SHULL

### GENETIC TERMINOLOGY

THE genetic terms recently proposed by G. H. Shull<sup>1</sup> seem to supply a real need. Their general use would certainly tend to reduce both the danger of ambiguity and the need for cumbersome descriptive phrases. Probably a few additional numerical terms, such as *dizygous* and *trizygous*,<sup>2</sup> would also be useful. Some existing equivalents have an obvious disadvantage with respect to compounding; the compound *trichrosomal*, for example, could not replace *trizygous* ("dependent on three pairs of chromosomes"). *Monozygous* and *pleiozygous*, although often interchangeable with *linked* and *unlinked*, should be useful; the latter, for example, to characterize genes that are located in several pairs of chromosomes but are not all necessarily unlinked with each other. These words are so interrelated among themselves, and so closely related to terms in general use, that all their advantages can be realized with little effort.

Shull suggests that it is time "to abandon the use of 'Mendelian' and 'non-Mendelian' as definite categories, and to adopt

<sup>1</sup> Shull, George H., "Mendelian or Non-Mendelian?" *Science*, N. S., 54: 213-216. Sept. 9, 1921.

<sup>2</sup> For the Greek numeral prefixes see Blakeslee, Albert F., "Types of Mutations and their Possible Significance in Evolution," *AM. NATURALIST*, 55: 254-267. 1921.

other terms which will have greater precision of meaning." Let us accept his timely proposal, which obviously applies especially to the more technical and precise terminology of genetics. With his new terms available, we may safely relegate the older ones, aside from historical references, to the more popular language of science.

Shull uses the older words to illustrate the application of his proposed terminology, but he does not specifically discuss their future delimitation in case they still retain a certain usefulness. Their future, I believe, deserves consideration. It seems certain that they will remain familiar words because of their historical value, in relation both to Mendel's work and to its earlier extension. Doubtless they will long be especially useful in the more popular presentation of genetic topics, to obviate burdensome use of more precise but more formidable expressions.

Historically, it is plain that the meaning of *Mendelian* has very largely kept pace with the widening conception of the fundamental applicability of Mendel's theory, although often, as Shull states, with the addition of qualifying expressions. When this widening process reaches the farthest point of practical usefulness, it leads to a broad definition of *Mendelism* which, I believe, deserves general acceptance.<sup>3</sup> It furnishes, for example, a convenient and familiar popular equivalent of *zeugis* for the characterization of "chromosomal heredity," at least so far as the inheritance phenomena of sexual reproduction are concerned. All other senses of *Mendelian* seem to require more technical detail in definition, or to be otherwise less useful for the purpose in question.

Again, the most significant conflicts of "Mendelism" with its critics have raged along a line of demarkation essentially corresponding to the broader definition. "Mendelians" once encountered frequent denials of the completeness and the generality of segregation, and frequent assertions that new somatic ratios implied other modes of inheritance of equal significance with Mendel's. The triumph of the chromosome theory has been the definitive establishment of the fundamental significance of "Mendelian heredity."

Finally, the broadest definition is fully justified logically, although it may not be superior in this respect to some other delimitations of the term. It may be held with good reason that

<sup>3</sup> Not forgetting, of course, that the older usage varies.

even linkage represents an *addition* to Mendel's genetic theory, rather than an *exception* to it. His scheme of independent separation and recombination of potentialities at gametogenesis is still adequate for the innumerable cases resembling his. Further, all genetic factors belong to theory rather than to observed fact, as do atoms and molecules. A gene is a *supposed* reality; it is something which many geneticists now *assume*, on the basis of evidence which they consider essentially conclusive, to be an *actual* part of a chromosome. The idea of lethal genes, therefore, or even that of the gene as a part of a chromosome, just as truly constitutes an addition to Mendel's genetic theory as a whole, as does the explanation of linkage ratios. The difference is, from this viewpoint, one of degree rather than of kind. If we admit some added hypotheses as Mendelian, why should we necessarily exclude any others which plainly relate to the same unified nuclear mechanism?

Even if we hold, as we may, that Mendel's theory has been revised as well as extended, its most fundamental feature, by present standards, is left unchanged. What, from our present viewpoint, is Mendel's most fundamental genetic conception? Is it not that of a *genetic shuffling*, a segregation and recombination, of genetic units which maintain their individuality throughout the processes of reproduction and of development?<sup>4</sup> Most usefully and even most commonly, it seems to me, *Mendelism* signifies the *general type or mode of inheritance* whose most fundamental principle of character distribution was discovered by Mendel; and this is "zeuxis," or chromosomal heredity, in sexual reproduction. This delimitation of *Mendelism* seems to me fully as good logically, better in accord with history, and much more promising of future usefulness in the field where the term is still needed, than any of the less inclusive senses in which it has been employed.

Dr. Shull says in correspondence, "I can see no objection to the *general non-technical use* of the words 'Mendelian' and 'Mendelism' in just the sense which you propose." And I believe that Morgan, East, Jones and Wright are far from being alone when they positively favor the broader definition.

<sup>4</sup> Bateson, W., "Mendel's Principles of Heredity." 1909. Cambridge Univ. Press. (See p. 13.)

Morgan, T. H., Sturtevant, A. H., Muller, H. J., and Bridges, C. B., "The Mechanism of Mendelian Heredity." 1915. New York, Henry Holt & Co. (See p. 1.)

Let us, then, take the course which is obviously more useful, and also honor the memory of the great pioneer of genetics, by applying his name to his great idea in all its later ramifications. But—wherever newer and more precise terms will better promote the science of genetics, let us be ready to use them. Shull's recent contribution to genetic terminology promises considerable and lasting usefulness.

HOWARD B. FROST

UNIVERSITY OF CALIFORNIA

IN connection with Dr. Shull's<sup>1</sup> interesting and important proposals concerning genetic nomenclature, attention should be called to a situation which neither these proposals nor the terminology in general use recognize. It is customary to refer to individuals carrying single X or Z chromosomes, as being heterozygous for sex-linked genes. For some time this has seemed to be ill-advised to the writer.

The situation prevailing in an XX or ZZ individual heterozygous for a sex-linked gene clearly differs from that of an XY (or XO), or a ZW individual in the vast majority of cases, though Schmidt's work on *Lebistes reticulatus*, to which Dr. Castle<sup>2</sup> recently called the attention of American workers, possibly indicates that for XY individuals it does not necessarily always differ. In the one case, usually there is a demonstrable allelomorph, not infrequently competitive enough in its expression to produce more or less of an intermediacy between the two homozygous forms. In the other, usually there is not.

The term heterozygous, as much as homozygous, indicates an allelomorphic pair, yet in XY and ZW individuals, with the one possible exception noted, a pair of sex-linked genes has not been demonstrated, and is clearly impossible for XO individuals. To all appearances the sex-linked genes in such individuals are without synaptic mates. They are therefore simple but not heterozygous.

In order to recognize this situation, and in a measure describe it without using presence and absence terminology, and in harmony with the terms proposed by Dr. Shull, I should like to suggest the noun *hemizeuxis* (a half yoking) and the corresponding adjective *hemizygous* (half yoked). Should such

<sup>1</sup> Shull, Geo. H., 1921, *Science*, N. S., 54: 213-216.

<sup>2</sup> Castle, W. E., 1921, *Science*, N. S., 53: 339-342.

a suggestion prove acceptable there would be the three adjective series: homozygous, heterozygous, and hemizygous, referring to the three possible conditions with respect to any single gene, namely, "like mates," "differing mates," and "no mate."

The term might also be used in cases where a non-deficient chromosome is paired with a deficient one. The deficient individual would be hemizygous for the genes at those loci of the non-deficient chromosome which were involved in the deficiency of its mate.

WILLIAM A. LIPPINCOTT

KANSAS AGRICULTURAL EXPERIMENT STATION

### CROSS-OVER VALUES IN THE FRUIT-FLY, *DROSOPHILA AMPELOPHILA*, WHEN THE LINKED FACTORS ENTER IN DIFFERENT WAYS

THE factors for bar, round, red and white eye are sex-linked, being located in the X-chromosome, as shown in inheritance. For example, when a bar-eyed male is mated to a normal female all the resulting male offspring (F1) are normal and all of the females bar eyed, as bar is dominant; that is, factors that occur in the X or first chromosome have a "criss cross" mode of inheritance following the distribution of the X-chromosomes, there being but one X-chromosome in the males and two in the females.

The relative positions of the linear series of factors in the X-chromosome of *Drosophila* have been determined by Morgan and Bridges (237 Carnegie Institution). Factors that lie near together in the chromosome are more likely to be transmitted in the same combinations to the gametes than those that lie far apart; that is, the strength of linkage depends on the distance apart of the factors. The failure to transmit the same combinations of factors that enter from the parents to all the offspring is due to a crossing-over of some of the factors. For example, a red bar-eyed fly, mated to a white round-eyed fly, give in the second generation (F2) white bar and red round-eyed flies, as well as flies like the original parents; that is, there has occurred a recombination of the factors due to crossing-over.

Are the cross-over values the same when the linked factors enter in different ways? My experiments performed in the University of Chicago Laboratories give data relative to this question. Using the presence and absence hypothesis, let (B) represent the factor for bar and (R) the factor for red, then let